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Situating Requirements Engineering methods within Design Science Research

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Abstract. *Design Science Research Methodologies (DSRM) are increasingly used to guide research in fields beyond Information Systems, in particular those of Requirements Engineering and Software Engineering (RE/SE). While a number of DSR methodologies have been developed by scholars in the RE/SE fields, there remains a certain level of confusion about the way in which the aim and scope of DSRM and those of methods typically used in RE/SE differ. This issue can be observed in graduate students' work as well as in published literature. In particular, the difference between the research orientation of DSRM and the solution orientation of RE/SE methods can be difficult to navigate. We propose to address this challenge by situating three RE/SE methodologies proposed in published literature within one common DSRM; doing so clarifies the scope of these methodologies and highlights ways in which the knowledge contributions of their results could be further enhanced. This effort is a first step towards providing better guidance to researchers who are new to design science research in order to ensure that recognized DSR principles are promoted and respected.*

Keywords: Design science research methodologies, engineering methods, design science research education

1 Introduction

Design Science Research (DSR) is a research paradigm that has become common ground in the field of Information Systems; it is also emerging as a legitimate approach in other fields such as computer science and software engineering [7, 19]. Indeed, its focus on the creation and validation of innovative artifacts able to solve human problems has made DSR attractive to researchers in these fields [16]. Advancements within DSR have helped to establish it as an approach that is both rigorous and relevant [7, 8, 23]. Their application and recommendations provide a basis for a systematic and adequate application of DSR principles.

Nevertheless, misunderstanding of DSR methods, concepts and outputs can still be observed among graduate students and researchers new to DSR. In fields such as Requirements Engineering and Software Engineering (RE/SE), such misunderstand-

ings may arise from an understandable confusion between methods typically used by practitioners in these fields – or developed for them or related users – and methodological guidelines provided by DSR methodologies. For example, a methodology is often described as the science of methods used in a particular area of study or activity [1, 13]. A methodology outlines the plan of action and process informing the choice and use of specific methods. It also connects the choice and use of the methods to desired outcomes. In relation to research, methodologies inform the choice and use of appropriate methods and the extent to which the methods are justified in the context of the purpose of the research [21, 22]. However, the term methodology can more generally refer to a set of methods used to solve a practical problem. This semantic ambiguity can make it difficult to understand, for example, how guidelines for performing Structured Analysis and Design [12] to create an application should be used within a research project using a Design Science Research (DSR) approach.

The objective of this research is to clarify the difference between a RE/SE – often practical – method and a DSR methodology in order to provide improved guidance to graduate students and researchers from those fields that are less familiar with DSR principles. To achieve this, we developed a framework that situates RE/SE methods and methodologies within a common DSR methodology. This framework could help RE/SE researchers improve, for example, their knowledge contributions. It could also prove useful in other fields, helping users with field-specific methods and methodologies to better articulate their research contributions. As a first step toward this objective, this research-in-progress analyzes a purposive sample of three RE/SE methodologies taken in extant literature and with which the authors of this paper are familiar. Each methodology is then placed within the well-known Design Science Research Methodology (DSRM) [14] in order to clarify its aims and scope. In addition, we highlight how using the DSRM might have helped the authors to enhance the knowledge contributions of their research.

The remainder of this paper is organized as follows: in Section 2 we describe the method used in our analysis; we then outline our analysis of three select RE/SE methodologies in Section 3. We discuss additional DSR methodologies and provide recommendations to improve the knowledge contributions of these methodologies in Section 4, and conclude with future work aiming to formalize this research-in-progress in Section 5.

2 Method

The Design Science Research Methodology (DSRM) offers conceptual principles, practice rules and a process for carrying out and presenting research in a manner that respects recognized principles of design science research [14]. As a methodology, the DSRM provides a template that can be used to present and evaluate research projects. The authors of the DSRM illustrate this by analyzing extant research projects in terms of the six iterative activities of the DSRM (problem identification and motivation; objective of the solution; design and development; demonstration; evaluation; communication), their entry point into the process, and their contribution [14]. However,

this was mainly accomplished to evaluate the methodology itself rather than the projects serving as cases.

In this paper, we effectively follow on the authors' proposition and use the DSRM as a template to evaluate three research projects focused on the development of methodologies and tools in the field of RE/SE. This allows us to clarify the aims, scope and outputs of each methodology from a design science research perspective. We then draw on other methodologies proposed within the body of literature on design science research to propose ways in which each research project could further articulate its knowledge contributions [7, 23].

3 Overview and analysis of three RE/SE methodologies

In this section, a brief overview of each methodology is first presented in Sections 3.1, 3.2, and 3.3. An analysis of these methodologies using the DSRM [14] is then presented in Section 3.4.

3.1 The Regulatory Intelligence Methodology

The Regulatory Intelligence Methodology (RIM) has been proposed to improve regulators' decisions making when they enforce compliance [4]. Its development was motivated by the current shift from prescriptive to outcome-based regulations, which brings challenges in terms of evaluating if the requirements of a regulation are satisfied, and to what extent. To address this challenge, RIM uses goal modeling and analysis [4] to facilitate the transformation of prescriptive regulations into outcome-based regulations with goals that can be measured, analyzed and reported using Business Intelligence (BI) tools. In its application, the RIM assumes the regulator is committed to introducing an outcome-based approach for regulation writing; the methodology thus consists of seven iterative steps that regulators should follow in order to state and implement regulations in a manner conducive to their monitoring.

3.2 The Business Intelligence - Enabled Adaptive Enterprise Architecture

The Business Intelligence - Enabled Adaptive Enterprise Architecture (BIEAEA) has been proposed to anticipate and proactively support the adaptation and evolution of enterprise architectures [2]. Its development was motivated by challenges common in current dynamic business environments where Information Systems (IS) are not often aligned to business objectives they support. Operating on the premise that IS provide information that decision makers use to meet business objectives, the BIEAEA provides a goal-oriented modeling procedure that links IS to decisions and business objectives. In its application, the BIEAEA framework consists of a model, a methodology and tool; together, these elements support the exploitation of goal, process, and indicator modeling, and analysis in order to specify the relationships between an organization's business objectives and information systems.

3.3 Business Intelligence Modelling

Business intelligence modeling (BIM) is a modeling technique and accompanying methodology that supports the exploration and monitoring of business objectives and risks according to chosen performance measures [10]. It aims to present a business-friendly viewpoint of data collected by an organization for operational, analytical, or strategic objectives [5]. This is mainly achieved through the provision of constructs for modeling hierarchical goal structures, and the performance of individual goals through associated performance indicators [5]. The accompanying methodology focuses on procedures for reasoning with models in a manner that allows the exploration of scenarios and the identification of strategies to achieve business objectives.

3.4 Analysis of three methodologies

Table 1 presents the main components of the Design Science Research Methodology (DSRM) [14] in the left-hand column, and the application of these components to the three methodologies presented above. Analyzing the Regulatory Intelligence Methodology (RIM) [4], the Business Intelligence - Enabled Adaptive Enterprise Architecture (BIEAEA) [2], and Business intelligence modeling (BIM) [10] as they are reported in literature highlights a first key point about their nature: from the perspective of the DSRM, these methodologies are used to develop artifacts, the output of research projects, rather than to guide the research process itself.

While they can certainly be understood as methodologies in the sense of sets of methods peculiar to needs within a body of knowledge, their use by professionals (regulators or business users) will most likely take them outside the realm of research. Secondly, while they have all been developed in the context of research problems, their contributions are stated in practical terms, hence in terms of their usefulness for practitioners. While this shows their relevance, none of these methodologies have been evaluated and hence contribution to the knowledge base of RE/SE remains to be articulated.

Table 1. Analysis of three RE/SE methodologies [4, 2, 10] using DSRM [adapted from 14]

DSRM components	Application of DSRM to RIM, BIEAEA, and BIM
Entry point into the research process	• **RIM, BIEAEA, BIM:** Goal-centered initiation.
Problem identification and Motivation	• **RIM:** Difficulty of evaluating if the requirements of outcome-based regulation are satisfied and to what extent. • **BIEAEA**: Challenges for businesses to adapt their enterprise architectures in the current dynamic business environment. • **BIM**: Business intelligence systems and displays tend to be organized around data structures rather than business users concerns.
Objective of the solution	• **RIM:** Provide practical means to transform regulations from prescriptive to outcome-based formats in a way that enables measurement, analysis, and reporting of their performance using BI tools. • **BIEAEA**: A method to connect information systems to decisions

DSRM components	Application of DSRM to RIM, BIEAEA, and BIM
	and business objectives in an organization with means to explore and evaluate different kinds of change. • **BIM:** Provide a modeling approach and methodology to bridge the business-level understanding of an enterprise with its representation in databases.
Design and development	• **RIM:** Use of goal-oriented modeling and analysis to create outcome-based regulations and evaluation strategies that facilitate analysis and reporting using BI tools. • **BIEAEA**: Use of goal-oriented modeling principles and tools to create a methodology, goal models and evaluation strategies for anticipating and supporting adaptation to change. • **BIM:** Extension of goal-oriented modeling constructs and development of a methodology to analyze business objectives and risks according to chosen performance measures.
Demonstration	• **RIM:** Proof-of-concept design was created, modified and applied to the needs of regulators in safety compliance and financial domains. • **BIEAEA**: Proof of concept design along with "well-formedness rules" to ensure models and their assumptions are accurate, was demonstrated. Qualitative interviews were collected to assess the BIEAEA's performance and limitations. • **BIM:** The relevance of BIM has been shown through a number of case studies.
Evaluation	• **RIM, BIEAEA, BIM:** Have not been evaluated.
Communication	• **RIM:** Manuscript and test scenarios related to the RIM have been published in peer-reviewed publications [4, 15, 17]. • **BIEAEA**: Manuscript and case study related to the BIEAEA have been published in conference proceedings [2, 3]. • **BIM:** The concepts and use of BIM have been communicated through a number of papers and articles [10,5, 6].
Contribution	• **RIM:** A procedure and supporting tool for using performance modelling to improve regulatory decision-making. • **BIEAEA**: A procedure and supporting tool for using goal analysis to anticipate and manage evolution in an organization's business objective and IS. • **BIM:** A model-based approach to reasoning about an enterprise's strategies in the context of its business environment, and in relation to its data and performance indicators.

4 Discussion

The methodologies presented in the previous section address tangible practical problems and leverage authors' deep domain knowledge to propose convincing means to

address them. The numerous peer-reviewed venues in which their concepts and demonstrations were published attest to their quality. Nevertheless, their analysis through the components of the Design Science Research Methodology (DSRM) [14] showed similar areas for improvement in terms of evaluation and contributions. In this section, we propose complementary design science research (DSR) methodologies that could have been used to further enhance the development and contributions of each methodology.

The research underlying each methodology addressed two complementary concerns, that of practical and knowledge problems. Their results in turn should then have practical and knowledge contributions. An appropriate methodology to address such nested problems relies on the regulative cycle [23]. This methodology provides a conceptual methodology for understanding the logic of practical problems. Using the regulative cycle, practical problems can be decomposed into knowledge subproblems and practical subproblems with useful guides for solving them. Whereas practical problems call for a change of the world so that it better agrees with given stakeholder goals, knowledge problems rather call for a change in our knowledge about the world [23]. In the context of the Regulatory Intelligence Methodology (RIM) [4], for example, practical problems include challenges in enforcing regulations in a manner that achieves the goals of the regulator; knowledge problems by contrast include the need to modify our knowledge about how regulated bodies respond to regulations. The former requires the development of a method and tool to evaluate regulations in regards to regulators' goals. The later requires evaluating proposed methods and tools in regards to their objective improvement of regulations enforcement.

As Table 1 shows, the authors of the three reviewed methodologies did not articulate such knowledge contributions. The knowledge contribution framework [42] could have been a tool to help them do so. According to this framework, reviewed methodologies fall in the category of "Exaptation", where existing solutions are adapted to solve new problem. This kind of solution can lead to both prescriptive and descriptive knowledge contributions [42]. Prescriptive contributions can happen at three levels: 1) Artifact implementation in specific contexts; 2) Operational principles such as constructs, methods, and models serving as a nascent design theory; and, 3) mid-range and grand theories about artifacts in context [42]. The three reviewed methodologies all show elements of knowledge contributions at levels 1 and 2, but not at level 3. Indeed, more advanced evaluations of each methodology would be required to arrive at well-developed design theories. More so, while the demonstrations provided for each methodology helps to answer value questions (knowing if the implemented artifacts satisfy stakeholder requirements), evaluation is needed to answer causal questions (objectively knowing if implemented artifacts have desired effects) [23]. This could be achieved, for example, using a number of strategies for generalizing SE theories [25]. Using these frameworks could have guided the authors of these methodologies to better articulate the knowledge contributions of their research, and to state their future work in terms of a more rigorous evaluation of their solutions in order to enhance their future contributions to the RE/SE knowledge base.

5 Conclusion

This research-in-progress stands as a proof-of-concept that existing Design Science research (DSR) methodologies can be used to analyze research developed in the field of Requirements Engineering/Software Engineering (RE/SE), in order to clarify the nature and scope of their research outputs and provide guidance to further their knowledge contributions. Given the increased use of DSR by graduate students and researchers new to this research approach – in the field of RE/SE and beyond –, providing such guidance is important to ensuring that DSR principles (embedded, among others, in its methodologies) are correctly applied. Maintaining recognized DSR standards in graduate work and published literature that use DSR as a research paradigm could in turn contribute to the recognition and relevance of DSR.

This research-in-progress addressed a limited number of articles given its early stage. To address this limitation, in our future work, we plan to ensure that a wider range of RE/SE papers are included in the study. This will ensure that, among other things, papers that have different DSRM entry points and weaknesses will be analyzed. Since research within requirements engineering is often concerned with stakeholder interactions, taken to be vital in eliciting quality and complete requirements, we will explore the possibility of using additional DSR methodologies or frameworks to analyze these papers. For example, Action Design Research, which recognizes that artifacts emerge in interactions with organizational elements [17], could provide a relevant analytical framework for interaction-focused methods in RE/SE. The results of this future research could serve as the basis for the development of guidelines for researchers wanting to adopt a DSR paradigm. These guidelines could usefully complement existing literature explaining how to apply DSR frameworks and methodologies [9, 20, 24].

6 Reference

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